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HABITAT SUITABILITY INDEX MODELS: GREAT EGRET

Fish and Wildlife Service

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This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

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HABITAT SUITABILITY INDEX MODELS: GREAT EGRET

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PREFACE

The habitat suitability index (HSI) model for the great egret presented in this report is intended for use in the habitat evaluation procedures (HEP) developed by the U.S. Fish and Wildlife Service (1980) for impact assessment and habitat management. The model was developed from a review and synthesis of existing information and is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1.0 (optimally suitable habitat). Assumptions used to develop the HSI model and guidelines for model applications, including methods for measuring model variables, are described.

This model is a hypothesis of species-habitat relations, not a statement of proven cause and effect. The model has not been field tested, but it has been applied to three hypothetical data sets that are presented and discussed. The U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help increase the utility and effectiveness of this habitat-based approach to fish and wildlife management. Please send any comments or suggestions you may have on the great egret HSI model to the following address.

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ACKNOWLEDGMENTS

Earlier versions of the habitat suitability index model and narrative for the great egret were reviewed by Dr. R. Douglas Slack and Jochen H. Wiese. The model's structure and functional relationships were thoroughly evaluated by personnel of the U.S. Fish and Wildlife Service's (FWS) National Coastal Ecosystems Team. Model and narrative reviews were also provided by FWS Regional personnel.

GREAT EGRET (*Casmerodius albus*)

INTRODUCTION

The great egret, also called common egret or American egret, is a large white heron in the order Ciconiiformes, family Ardeidae. Great egrets stand 94.0-104.1 cm (37-41 inches) tall and have a wing spread to 139.7 cm (55 inches) (Terres 1980). The species is associated with streams, ponds, lakes, mud flats, swamps, and freshwater and salt marshes. The birds feed in shallow water on fishes, amphibians, reptiles, crustaceans and insects (Terres 1980).

Distribution

The great egret is a common breeding species in all coastal areas south from southern Oregon on the Pacific coast and from Maine on the Atlantic coast; in riverine, palustrine and estuarine habitats along the coast of the Gulf of Mexico; and in the Eastern-Central United States (Palmer 1962; Erwin and Korschgen 1979; American Ornithologists' Union 1983). The great egret undergoes an extensive postbreeding dispersal that extends the range of the species to most of the United States exclusive of the arid Southwest (Byrd 1978). Young birds hatched in Gulf coast colonies tend to move northward for a short period (Byrd 1978; Ogden 1978). However, with the onset of colder weather most great egrets and other herons migrate south and many winter along the gulf coast in Texas, Louisiana, and Florida (Lowery 1974; Oberholser and Kincaid 1974; Byrd 1978). Analysis of banding data indicates that many birds winter in Cuba, the Bahamas, the Greater and Lesser Antilles, Mexico, and Central America (Coffey 1948). Lowery (1974) suggested that during severe winters, a higher proportion of the population winters farther south.

Life History Overview

Great egrets nest in mixed-species colonies that number from a few pairs to thousands of individuals. A colony may include other species of herons, spoonbills, ibises, cormorants, anhingas, and pelicans. Colony and nest-site selections begin as early as December along the gulf coast, but most great egrets do not initiate nesting activities until mid-February or early March (Bent 1926; Oberholser and Kincaid 1974; Chaney et al. 1978; Morrison and Shanley 1978). Eggs have been recorded from March through early August, and young have been observed in nests from mid-May through late August (Oberholser and Kincaid 1974; Chaney et al. 1978). Clutch size varies from one to six eggs per nest, but three to four eggs is most common (Bent 1926). Incubation period in a Texas colony ranged from 23 to 27 days (Morrison and Shanley 1978). The first flights of young have been noted about 42 days after hatching (Terres 1980).

SPECIFIC HABITAT REQUIREMENTS

Food and Foraging Habitat

Fish constitute up to 83% of the great egret's diet (Hoffman 1978). Most fish taken by great egrets are minnow-sized (less than 10 cm or 3.9 inches), but fish up to 36 cm (14 inches) can be captured and swallowed (Willard 1977; Schlorff 1978). Other major food items include insects, crustaceans, frogs, and snakes, while small mammals, small birds, salamanders, turtles, snails, and plant seeds are occasionally taken (Baynard 1912; Bent 1926; Hunsaker 1959; Palmer 1962; Genelly 1964; Kushlan 1978b).

Little specific information exists on the food habits of various age classes of great egrets. An adult great egret weighing 917 g (32.3 oz) (Palmer 1962) may require approximately 110 g (3.9 oz) of food per day (estimated by using the wading bird weight-daily food requirement model proposed by Kushlan 1978b). Daily food requirements are undoubtedly higher during the nesting season when adults are feeding young (Kushlan 1978b).

Great egrets usually forage in open, calm, shallow water areas near the margins of wetlands. They show no preference for fresh-, brackish, or saltwater habitat. Custer and Osborn (1978a,b) found that feeding habitat selection in coastal areas of North Carolina varied daily with the tidal cycle. During low tide, great egrets fed in estuarine seagrass beds. During high tide, freshwater ponds and the margins of Spartina marshes were used. Inland, great egrets feed near the banks of rivers or lakes, in drainage ditches, marshlands, rain pools (Bent 1926; Dusi et al. 1971; Kushlan 1976b), and occasionally in grassy areas (Weise and Crawford 1974). Feeding sites are generally not turbid and are fairly open with no vegetative canopy and few emergent shoots (Thompson 1979b).

Great egrets forage singly, in single-species groups, and in mixed-species associations (Kushlan 1978b). Great egrets generally fly alone to feeding sites (Custer and Osborn 1978a,b) and may use the same feeding site repeatedly. The density and abundance of fish at a given location in estuarine habitats may vary with season, time of day, tidal stage, turbidity, and other factors. If feeding success is low, great egrets may move to other areas (Cypert 1958; Schlorff 1978) and join other conspecifics in good feeding habitats (Custer and Osborn 1978a,b). Most instances of group feeding have been observed during specific environmental conditions, such as lowered water levels, that tend to concentrate prey (Kushlan 1976a,b; Schlorff 1978).

Meyerriecks (1960, 1962) and Kushlan (1976a, 1978a,b) provided detailed information on hunting techniques employed by great egrets. The "stand-and-wait" and "slow-wade" methods are used most frequently. Because of their long legs, great egrets can forage in somewhat deeper water than most other herons. In New Jersey, foraging depths ranged from 0 (standing on the bank while fishing) to 28 cm (11 inches), but depths ranging from 10 cm to 23 cm (4 to 9 inches) were most commonly used (Willard 1977). In North Carolina, great egrets fed in water with a mean depth of 25.1 cm (9.8 inches) in Spartina habitat and of 17.4 cm (6.8 inches) in non-Spartina habitat (Custer and Osborn 1978b). Mean water depth was 20 cm (7.9 inches) for foraging great egrets in California (Hom 1983). In addition to wading, great egrets can feed by alighting on the surface of deep waters to catch prey, a method rarely employed (Reese 1973; Rodgers 1974, 1975).

Although recent declines of great egret populations in the central coastal region of Texas occurred simultaneously with declines in coastal marine and estuarine fish populations (Chapman 1980), no causal relationship has been proven. At present there are no known management practices that provide suitable food alternatives for piscivorous species, such as the great egret, during periods of fish population decline. Known fish nursery and feeding areas need protection from destruction or habitat alteration to ensure adequate prey populations for fish-eating birds.

Cover

Nesting. The great egret is a versatile nester, using trees, shrubs, and ground sites in riparian forest, swamp, and island habitats. Most colony sites in Texas are on natural or dredged-material islands, but several inland sites are known (Chaney et al. 1978). Most colony sites in Louisiana are associated with coastal fresh- or brackish water marshland (Portnoy 1978). In some cases, great egrets successfully occupy artificial nesting structures (Wiese 1976). Few colony sites are known that lack a substantial water barrier. Most inland sites are in swamps where nest trees grow in water at least 0.6 m (2 ft) deep during the breeding season (Meanley 1955; Wiese 1976). Such colony isolation may be important to reduce predation (Taylor and Michael 1971) or other disturbance.

Nest height varies with vegetation height, and nests within a mixed-species heronry tend to be stratified vertically in an order that correlates with species body length (Burger 1978). Thus, great egret nests are usually higher than the nests of all other species except the great blue heron (Ardea herodia). Most great egret nests are situated near the top, but just below the crown, of vegetation (Meanly 1955; Teal 1965; Pratt 1972; Girard 1976; Wiese 1976; Maxwell and Kale 1977; Portnoy 1978; Thompson 1979; Beaver et al. 1980). Terres (1980) noted that nests were usually about 6.1-12.2 m (20-40 ft) above the ground in medium sized trees. In coastal shrub-scrub vegetation, mean nest heights of 2.8 m (9.2 ft) (Maxwell and Kale 1977) and 1.7 m (5.6 ft) (Beaver et al.) have been reported. McCrimmon (1978) identified several additional characteristics of great egret nest placement that differ from other species: great egrets nested in larger trees, closer to the edge of the heronry, and in more open and accessible sites. Trees and shrub species where great egrets in coastal Texas and Louisiana build nests are listed in Table 1.

Because great egret nests are large (0.6 m or 2 ft) in diameter (Girard 1976), they are usually supported by several limbs that have a combined mean diameter of 5.9 cm (2.3 inches) (McCrimmon 1978). Thus, suitable nest site criteria may be related not only to available space, but also to minimum nest support. If vegetation for suitable nest support is present, great egrets can nest close to each other. Nearest nest distances of 1 m (3.3 ft) have been found in densely packed colonies (Beaver et al. 1980).

Table 1. Scientific name, common name, and mean vegetation height of all plants reported as nest species for great egrets in Texas and Louisiana.

Scientific name	Common name	Mean height (m)	Reference
Acacia farnesiana	Huisache	1	Goering and Cherry 1971
Acer rubrum	Red maple	1	Taylor and Michael 1971
Avicennia germinans	Black mangrove	1	Chaney et al. 1978
Baccharis halifolia	Sea myrtle	1	Burger 1978 Chaney et al. 1978
Celtis lindheimeri	Hackberry	5	Chaney et al. 1978
Cephalanthus occidentalis	Buttonbush	7	Taylor and Michael 1971
Iva frutescens	Marsh-elder	1	Chaney et al. 1978 Portnoy 1977
Nyssa sp.	Tupelo	7	Portnoy 1977
Opuntia lindheimeri	Prickly-pear	1	Chaney et al. 1978
Prosopis glandulosa	Mesquite	2	Chaney et al. 1978
Salix nigra	Black willow	5	Wiese 1976
Sambucus canadensis	Common elder-berry	1	Chaney et al. 1978
Scirpus spp.	Bulrush	1	Oberholser and Kincaid 1974
Spartina patens	Marshhay cordgrass	1	Chaney et al. 1978
Tamarix sp.	Salt cedar	2	Burger 1978
Taxodium sp.	Cypress	8	Simmons 1959
Zanthoxylum clava-herculis	Tickle-tongue	5	Chaney et al. 1978

Although great egrets usually nest in the crowns of trees and shrubs, ground nests have been reported in Texas (Chaney et al. 1978) and elsewhere (McCrimmon 1978). Ground nests are rare and usually found adjacent to a heronry on an island; apparently, ground nesting occurs when there is a lack of suitable nest sites in trees or shrubs in or near a dense colony.

Colony size of single-species or mixed-species heronries varies from four nests in a single tree or shrub to several thousand nests scattered throughout a heterogeneous vegetative association covering 6 ha (15 acres) or more (Portnoy 1977; Chaney et al. 1978; Nesbitt et al. 1982). Great egret nests tend to be clumped within a mixed-species heronry because their nest placement requirements differ from other herons.

There is evidence that herons re-use colony sites (Custer and Osborn 1977). Repeated use of a site may depend upon several factors: (1) prior (successful) experience at a site (Wiese 1978b); (2) the presence of other herons, particularly the great blue heron, which begins nesting before the great egret (Chaney et al. 1978); and (3) the remnants of old nests (Wiese 1976). Colony abandonment can result from the destruction of nest vegetation (Wiese 1979) or from changes in feeding habitat (Custer et al. 1980). Human disturbance and predation have also been implicated as factors contributing to colony abandonment (Chaney et al. 1978).

Non-nesting. Great egrets roost nocturnally in communal sites when not breeding. These sites are usually at the tops of tall trees in dense thickets or in the tops of short trees on islands or over water (Bent 1926). Roosting sites may be used for many years, and some may also be used for nesting. The characteristics of roost sites are similar to the those of nest sites, but no specific data have been published.

Water

The physiologic water requirement of great egrets is probably met during feeding activities in aquatic habitats (Dusi et al. 1971). Water depth affects the quantity, variety, and distribution of food and cover; great egret food and cover needs are generally met between the shoreline and water 0.5 m (1.6 ft) deep (Willard 1977).

Interspersion

Suitable habitat for the great egret must include (1) extensive shallow, open water habitat from 10 to 23 cm (4 to 9 inches) deep (Willard 1977); (2) food species present in sufficient quantity (Custer and Osborn 1977); and (3) adequate nesting or roosting habitat close to feeding habitat. Most great egrets at a colony in North Carolina flew less than 4 km (2.5 mi) from nesting colonies (and presumably, from roosting sites) to feeding areas (Custer and Osborn 1978a), but flight distances of up to 36 km (22.4 mi) have been recorded in the floodplain of the Upper Mississippi River (Thompson 1979b).

Several heronries may be close together. Great egrets from one colony may fly over or near an adjacent colony, but rarely feed in the same areas as conspecifics from the adjacent colony (Thompson 1979b).

Special Considerations

Human disturbance and habitat alteration are the two factors considered most responsible for the decline of the great egret throughout its range (Custer and Osborn 1977; Portnoy 1977; Chaney et al. 1978; Chapman 1980). Great egrets are sensitive to human disturbance and may abandon nests or entire colonies as a result of human activity (Goering and Cherry 1971; Mendoza and Ortiz 1974). Human presence in a colony may cause nest desertion, which leads to high nestling mortality from exposure, predation, and accidents (Morrison and Shanley 1978).

Traditional colony sites and nocturnal roosts should be preserved. Secondary sites of similar ecologic constitution are also important. High heron density within a colony may destroy nest vegetation by the effects of guano buildup and, to a lesser extent, trampling (Wiese 1978a,b). When this type of habitat destruction occurs, great egrets may pioneer adjacent suitable sites.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The habitat suitability index (HSI) models in this report were developed for application in coastal wetland habitats in Texas and Louisiana. Because there are few differences in habitat requirements along the Atlantic coast, the remainder of the gulf coast, and inland sites in the Southeastern United States, the HSI models may also be used to evaluate potential habitat in those areas.

Season. These models will produce HSI values based upon habitat requirements of great egrets during the breeding season (February to August). Because there is no apparent seasonal difference in feeding habitat preference and because winter nocturnal roosts are similar to nesting sites, the HSI models may also be used to evaluate winter habitat for the great egret.

Cover types. Great egrets nest on upland islands and in the following cover types of Cowardin et al. (1979): Estuarine Intertidal Scrub-Shrub wetland (E2SS), Estuarine Intertidal Forested wetland (E2FO), Palustrine Scrub-Shrub wetland (PSS) (including deciduous and evergreen subclasses), and Palustrine Forested wetland (PFO) (including deciduous and evergreen subclasses). Great egrets may also feed in these wooded wetlands, but preferred feeding areas may be any one of a wide variety of wetland cover types (Table 2).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat required before an area can be occupied by a particular species. Specific information on minimum areas required by great egrets was not found in the literature. If local information is available to define the minimum habitat area, and less than this amount of area is available, the HSI for the species will be zero.

Verification level. The output of these HSI models is an index between 0 and 1.0 that is believed to reflect habitat potential for great egrets. Two biologists reviewed and evaluated the great egret HSI model throughout its development: Dr. R. Douglas Slack, Texas A&M University, College Station, and Jochen H. Wiese, Environmental Science and Engineering Company, Gainesville, Florida. Their recommendations were incorporated into the model-building effort. The authors, however, are responsible for the final version of the models. The models have not been field-tested.

Table 2. Great egret feeding habitat types. Classification follows Cowardin et al. (1979).

System	Subsystem	Class	Abbreviation
Estuarine	Intertidal	Aquatic Bed	E2AB
		Emergent	E2EM
		Forested	E2FO
		Stream Bed	E2SB
		Scrub-Shrub	E2SS
		Unconsolidated Shore	E2US
Riverine	Tidal	Aquatic Bed	R1AB
		Emergent	R1EM
		Unconsolidated Bottom	R1UB
		Unconsolidated Shore	R1US
	Lower Perennial	Aquatic Bed	R2AB
		Emergent	R2EM
		Unconsolidated Bottom	R2UB
		Unconsolidated Shore	R2US
	Intermittent	Stream Bed	R4SB
Lacustrine	Littoral	Aquatic Bed	L2AB
		Emergent	L2EM
		Unconsolidated Bottom	L2UB
		Unconsolidated Shore	L2US
Palustrine		Aquatic Bed	PAB
		Forested	PFO
		Emergent	PEM
		Scrub-Shrub	PSS
		Unconsolidated Bottom	PUB
		Unconsolidated Shore	PUS

Model Descriptions

Overview. Separate HSI models were developed to evaluate great egret feeding and nesting habitats. No attempt was made to integrate these two models into a single, overall habitat model for the following reasons. As noted previously, most great egrets fly less than 4 km (2.5 mi) from nesting or roosting sites to feeding areas, but they may travel up to 36 km (22.4 mi). HSI models are intended primarily for use in impact assessment and may be applied in relatively small study areas. The study area for great egret may or may not contain both feeding and nesting cover types, and great egrets may use habitat outside the study area boundaries. An HSI model integrating food and nesting requirements may assign a low or no value to an area with cover types that supply only one of these requirements when the remaining requirement is met outside the area. Similarly, a single HSI model would downgrade the value of an area that had high-quality nesting habitat and where birds were bypassing low-quality feeding sites to use higher quality feeding sites outside the area. Separate models that evaluate potential feeding or potential nesting habitat quality avoid problems of the type outlined above and retain simplicity in model application. The relationships of habitat variables to the feeding and nesting HSI values are illustrated in Figure 1.

Feeding HSI model. Great egret feeding habitat suitability is related to prey availability. Habitat suitability is optimal when two conditions are met: (1) the populations of minnow-sized fish are high; and (2) shallow open water (necessary for successful prey capture), aquatic vegetation (necessary for prey survival and reproduction), and deeper water are present in a ratio that maximizes prey density and minimizes hunting interference. Use of this model assumes that deep or permanent water environments are not limiting in coastal habitats and that fish populations are distributed uniformly. Because great egrets hunt a variety of species in many different habitat types, a general approach to modeling feeding habitat suitability is presented. Suitability of all wetland cover types for feeding is determined by integrating two factors: (1) the abundance of prey and (2) the accessibility of prey.

The abundance of prey is determined by the ability of the habitat to support the major prey species, especially minnow-sized fish. It is assumed that the abundance of major prey species is related to the primary and secondary productivity of the aquatic habitat; however, few field studies have documented this relationship. The model assumes that prey abundance is not limiting in coastal habitats. Therefore, the accessibility of prey is used as the indicator of feeding habitat suitability.

The accessibility of prey is determined by water depth and percentage cover of aquatic vegetation. A wetland with 100% of its area covered by water 10-23 cm (4-9 inches) deep is assumed to be optimal for feeding by great egrets (V_1). Although an absence of submerged or emergent vegetation would render fish species most vulnerable to capture, it is unlikely that many prey species would use such an area because it totally lacks cover. The model assumes, therefore, that optimal conditions for both the occurrence and susceptibility to capture of prey species exist when 40%-60% of the wetland substrate is covered by submerged or emergent vegetation (V_2). When such vegetation is

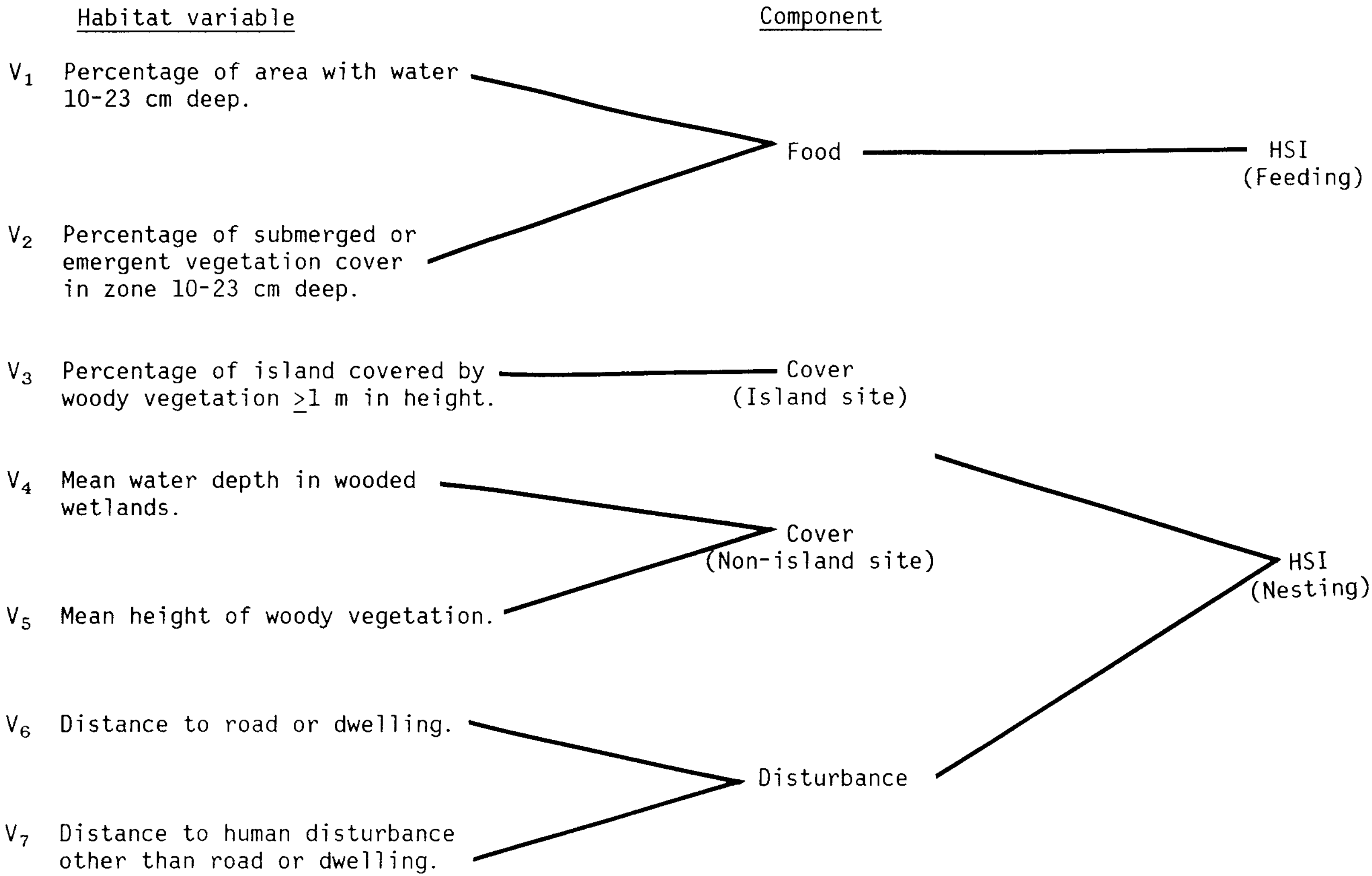


Figure 1. Relationships of habitat variables and components to the separate HSI models for great egret feeding and nesting habitats.

lacking, the habitat has a low value for feeding great egrets because small fish may use unvegetated water that is too shallow for their larger aquatic predators.

Nesting HSI model. The suitability of potential nesting sites for great egrets is determined by two factors: cover and disturbance (Figure 1). In this model, ground nesting is not considered because it involves few individuals, occurs in proximity to "normal" colonies, and may reflect a response to overcrowding rather than site preference.

Cover for nesting great egrets depends on vegetation characteristics and the presence of water barriers. On islands surrounded by deep or wide water barriers, great egrets nest in a wide variety of habitats ranging from low (1 m, or 3.3. ft) shrubs or grasses with dense canopies, to tall trees. Therefore, cover suitability of nesting habitat on islands is assumed to be related to the percentage of the island area having woody vegetation equal to or exceeding 1 m (3.3 ft) in height (V_3). Optimal habitat is present when 60% or more of the island supports woody vegetation equal to or exceeding 1 m in height. For the application of this model, islands are defined as sites less than 5 ha (12.4 acres) and completely surrounded by open water. Islands can be either along the coast or located inland in freshwater habitats.

In any given area, some or all of the great egret population may nest in non-island sites even though island habitats with suitable cover types are available. Non-island nest sites are found in shrubs or trees in seasonally (during the great egret nesting season) or permanently flooded areas such as the Estuarine Intertidal and Palustrine Scrub-Shrub and Forested wetlands (Cowardin et al. 1979). For such areas, the model assumes that nesting suitability varies with water depth (V_4) and that a water depth of 0.6 m (2 ft) or more reduces access by potential predators and represents optimal conditions for nesting. The mean height of woody vegetation in non-island sites must exceed 7 m (23 ft) to be optimal for nesting by great egrets (V_5).

Great egrets are sensitive to disturbance from humans and predators, especially during the breeding season. Boating and other water activities do not disturb nesting great egrets if they occur 50 m (164 ft) or more from the colony, the noise level is normal (no horns or other loud noises), and no humans walk in or near the colony. No colonies are known to occur within 0.5 km (0.3 mi) of a roadway or human dwelling. The model assumes that as the distance from human disturbance increases, the suitability of a site also increases. Sites 0.5 km (0.3 mi) or closer to a roadway or dwelling (V_6) are unsuitable for nesting by great egrets. Optimal sites must be at least 50 m (164 ft) from a channel or other potential source of human disturbance (V_7).

Suitability Index (SI) Graphs for Model Variables

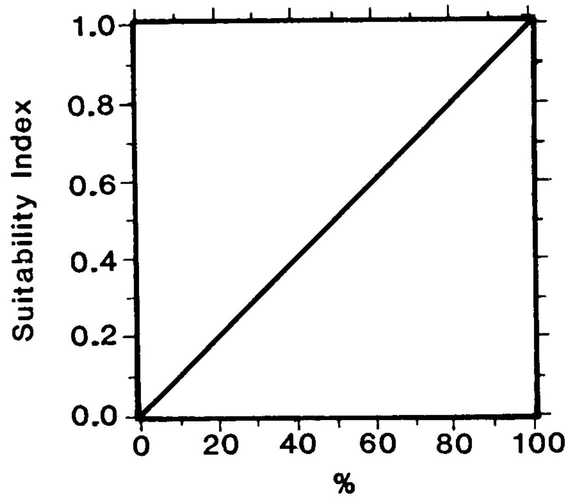
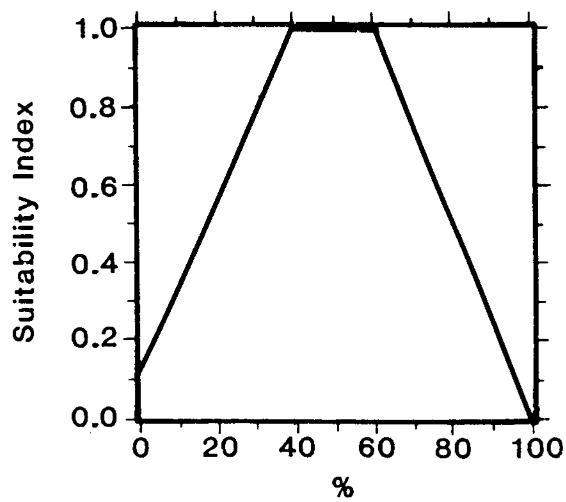
This section provides graphic representation of the relationship between habitat variables and habitat suitability for the great egret in wetland (see Table 2 for abbreviations) and upland (U) cover types. The SI values are read directly from the graph (1.0 = optimal suitability, 0.0 = no suitability) for each variable. Assumptions used in developing the SI graph for each variable appear in Table 3.

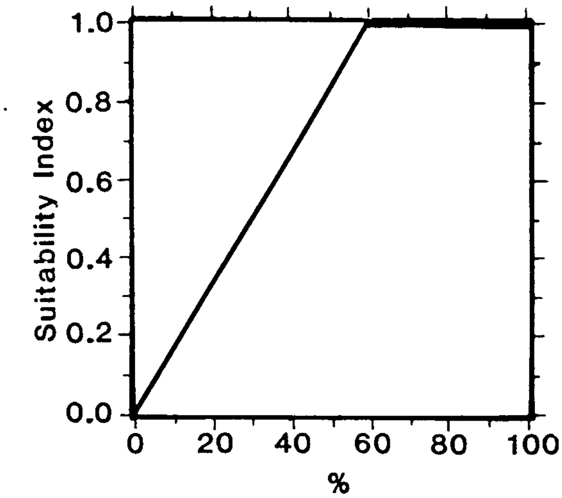
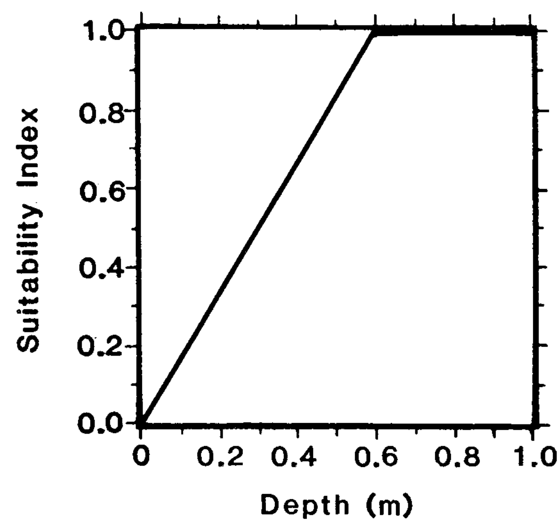
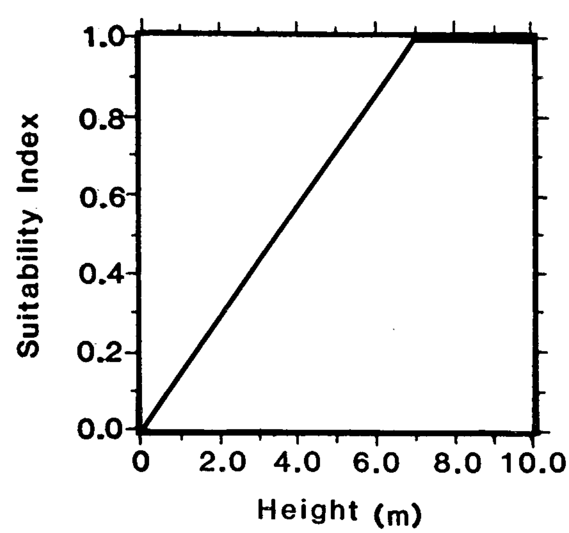
Table 3. Data sources and assumptions for great egret suitability indices.

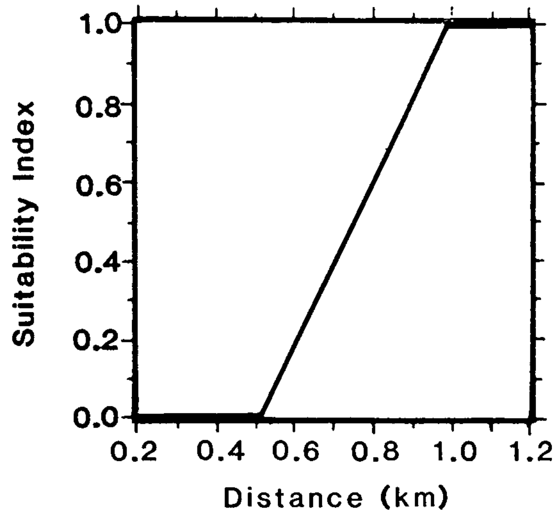
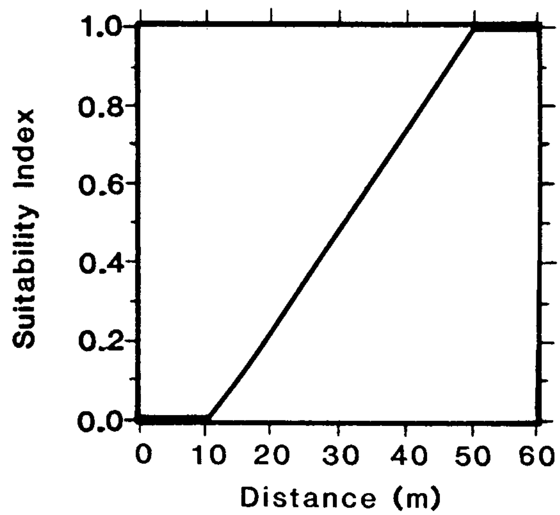
Variable and source		Assumption
V_1	Willard 1977	Prey is most accessible in water depths of 10-23 cm (4-9 inches).
V_2	Willard 1977	Substrates with 40%-60% coverage of emergent or submerged vegetation provide the optimum balance between cover for prey species and vulnerability of prey to capture by great egrets.
V_3	Chaney et al. 1978 Portnoy 1978	Suitability of nesting/roosting habitat on islands is positively related to the percentage canopy cover of woody vegetation $\geq$ 1 m (3.3 ft) tall.
V_4	Meanley 1955 Wiese 1976	Optimal nesting habitat for non-island sites is found when mean water depth beneath the woody vegetation is equal to or deeper than 0.6 m (2 ft).
V_5	Pratt 1972 McCrimmon 1978 Wiese 1978b Beaver et al. 1980	Suitability of nesting/roosting habitat on non-island sites increases with vegetation canopy height; optimum mean height equals or exceeds 7 m (23 ft).
V_6	(a)	Human disturbance is detrimental to great egret nesting/roosting. Optimal habitat occurs where the nearest road or dwelling is 0.5 km (0.3 mile) or farther from the site.
V_7	(a)	The optimal distance from potential nesting/roosting sites to disturbance other than roads or dwellings exceeds 50 m.

[a]These variables are not discussed in the literature on the great egret; they were derived from general discussions in Thompson (1979) and Rodgers and Burger (1982), from personal observations, and from results of other colonial seabird studies.

The SI graphs are based on the assumption that the suitability of a particular variable can be represented by a two-dimensional linear response surface. Although there may be interdependencies and correlations between many habitat variables, the model assumes that each variable operates independently over the range of other variables under consideration. Habitat abbreviations are defined in Table 2.

Habitat	Variable		Suitability Graph
All habitats in Table 2.	V_1	Percentage of study area with water 10-23 cm deep. In tidal areas, use depth at mean low tide. In nontidal areas, use average summer conditions.	
All habitats in Table 2.	V_2	Percentage of substrate in zone 10-23 cm deep covered by submerged or emergent vegetation.	

Habitat	Variable		Suitability Graph
E2SS,E2FO,U	V_3	Percentage of island covered by woody vegetation $\geq$ 1 m in height.	
E2SS, E2FO, PSS, PFO	V_4	Mean water depth in wooded wetlands.	
E2SS, E2FO, PSS, PFO	V_5	Mean height of woody vegetation.	

Habitat	Variable		Suitability Graph
E2SS, E2FO, PSS, PFO, U	V_6	Distance to road or dwelling.	
E2SS,E2FO, PSS, PFO, U	V_7	Distance to human disturbance other than road or dwelling.	

Component Index Equations and HSI Determination

The following equations are suggested for combining individual variable SI values into component indices and for obtaining the final HSI value. The HSI for feeding (or nesting) habitat is set at 0 if no cover type suitable for nesting (or feeding) can be located within 36 km (22.4 mi) of the study area.

Feeding HSI.

Component	Equation
Food (F)	$\dfrac{SI_{V_1} + SI_{V_2}}{2}$

HSI=F

Nesting HSI

Component	Equation
Cover, islands (C_i)	SI_{V_3}
Cover, non-islands (C_n)	$(SI_{V_4} \times SI_{V_5})^{1/2}$
Disturbance (D)	$(SI_{V_6} \times SI_{V_7})^{1/2}$

HSI (Islands) = C_i or D, whichever is lower.

HSI (Non-islands) = C_n or D, whichever is lower.

Data representing three hypothetical study areas for great egret were used to calculate sample HSI values (Table 4). The HSI values obtained are believed to reflect the potential of the areas to support feeding or nesting great egrets.

Field Use of Models

The level of detail needed for application of these models will depend on time, money, and accuracy constraints. Detailed field sampling of all variables will provide the most reliable and replicable HSI values. Any or all variables can be estimated to reduce the amount of time or money required to apply the models. Increased use of the subjective estimates decreases reliability and replicability, and these estimates should be accompanied by appropriate documentation to insure that decisionmakers understand both the method of HSI determination and quality of data used in the model. Techniques for measuring habitat variables included in the great egret HSI models are suggested in Table 5.

A project area may contain both potential feeding and nesting habitat. To decrease the cost and time necessary to evaluate the area, assume that food is not limiting and apply only the nesting HSI model. This recommendation is based upon the following assumptions: (1) in most coastal areas of Texas and Louisiana, aquatic habitats suitable for feeding are abundant and are, therefore, less of a limiting factor to great egrets than are suitable nesting sites; and (2) nesting value is easier and more accurately estimated by using subjective methods than is food value. The variables used to measure food

Table 4. Calculations of suitability indices (SI), component indices, and habitat suitability indices (HSI) for three sample data sets using habitat variable (V) measurements and the great egret HSI model equations.

Model element	Data set 1 Data	Data set 1 SI	Data set 2 Data	Data set 2 SI	Data set 3 Data	Data set 3 SI
Variables						
V_1	60%	0.60	-	-	-	-
V_2	90%	0.25	-	-	-	-
V_3	-	-	75%	1.0	-	-
V_4	-	-	-	-	0.27 m	0.45
V_5	-	-	-	-	6 m	0.86
V_6	-	-	1.0 km	1.0	0.75 km	0.5
V_7	-	-	25 m	0.38	50 m	1.0
Component indices						
F	0.43		-		-	
C_i	-		1.0		-	
C_n	-		-		0.62	
D	-		0.61		0.71	
HSI						
Feeding	0.43		-		-	
Nesting	-		0.61		0.62	

value are more indirect than those used to measure nesting value. This reflects the difficulties involved with measuring prey abundance, prey distribution, and prey accessibility.

A major assumption of the nesting HSI model is that all habitat areas with appropriate cover types have some potential value to great egrets. However, it is difficult to assess this potential because of two factors: (1) traditional use of past colony sites, and (2) the enhancement of a site by the presence of other herons. These two factors are usually, but not always, interrelated. Great egrets tend to use the same colony site in successive years until the site is degraded, and the site may include great blue herons. When applying the HSI model, the user should be aware that an area known to be used by great egrets (or great blue herons) is more likely to be used in future years than an area with an equal HSI value not known to have a history as a colony site.

Table 5. Suggested measurement techniques for habitat variables used in the great egret HSI models.

Variable	Suggested technique
V_1	The percentage of the area with water 10-23 cm (4-9 inches) deep can be determined by line transect sampling of water depth.
V_2	The percentage of substrate in the 10-23 cm (4-9 inches) water depth zone covered by submerged or emergent vegetation can be determined from available cover maps, aerial photographs, or by line transect sampling.
V_3	The percentage of an island covered by woody vegetation $\geq$ 1 m (3.3 ft) in height can be determined by measuring the height of randomly selected vegetation with a hypsometer or altimeter (Hays et al. 1981).
V_4	Mean water depth beneath woody vegetation on non-island sites can be determined by line transect sampling of water depth.
V_5	Mean height of woody vegetation on non-island sites can be measured by using a hypsometer or altimeter (Hays et al. 1981) on randomly selected vegetation.
V_6,V_7	Distance to disturbance can be measured on maps or aerial photographs. The disturbance location should be marked and the straight line distance measured from the disturbance to the middle of the potential nest/roost site.

If two or more distinct units of either potential feeding or nesting habitat are present within the project evaluation area, a single feeding or nesting index value for the project may be obtained by weighting the HSI of each unit by its area. When a weighted HSI is desired, the following equation should be applied:

$$HSI = \frac{\sum_{i=1}^{n} HSI_i A_i}{\sum A_i}$$ where n=number of distinct units of habitat, HSI_i=HSI of $unit_i$, A_i=area of $unit_i$

Interpreting Model Output

The HSI value obtained by applying the great egret models may have no relationship to actual population levels. Great egret population levels may be determined by nonhabitat factors, such as competition and predation, excluded from the models. Model outputs can be used, however, to compare the potential of two areas to support feeding or nesting great egrets at a single point in time. HSI values can also be used to compare the potential of a single area to support great egrets at future points in time.

ADDITIONAL HABITAT MODELS

No other habitat model for the great egret was located.

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A review and synthesis of existing information were used to develop a habitat model for great egret (Casmerodius albus). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1.0 (optimally suitable habitat) for coastal wetland areas along the gulf and Atlantic coasts. Habitat suitability indices are designed for use with the habitat evaluation procedures previously developed by the U.S. Fish and Wildlife Service. Guidelines for great egret model applications and techniques for measuring model variables are described.

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